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22 April 1963

Memorandum

To: Distribution List

From: W. H. Radford

Subject: Draft Report of SAB ad hoc Committee on Space Radiation Effects

Enclosed herewith is a draft report of our ad hoc committee. In compiling this I have tried to incorporate the substance, if not the exact language of the material prepared in rough form at our meetings on 29-30 January and 26 February.

I also return herewith - to each author - the original material which I received following each meeting.

I welcome your comments on the draft report, together with any suggestions you have for changes. If possible, please send these to me on or before 3 May 1963.

W. H. Radford

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Rg H652935

DRAFT

Report of the
Scientific Advisory Board
ad hoc Committee
on Space Radiation Effects

April 1963

Table of Contents

DRAFT

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DRAFT

Report of the Scientific Advisory Board Ad Hoc Committee on Space Radiation Effects

April 1963

1.0 Introduction

On 8 October 1962 the Secretary, Scientific Advisory Board, proposed to the USAF Deputy Chief of Staff, Research and Technology, that the SAB be authorized to undertake a review of space radiation effects likely to be of importance to the Air Force.

This review was approved and the Ad Hoc Committee on Space Radiation Effects was established. The first meeting of the ad hoc Committee, held in the Pentagon on 13 December 1962, was devoted to discussion of objectives and procedures for the review, and to revision of the problem statement.*

Additional meetings were held at Aerospace Corporation, El Segundo, California, on 29-30 January 1963**, and at the Rand Corporation, 1000 Connecticut Avenue, Washington, D. C. on 26 February 1963.

*See Appendix I

**See Appendix II

This report is limited to discussion of aspects of the problem of trapped natural and artificial particles and includes recommendations for action by the Air Force to improve capability to design survivable operational space systems.

2.0 Discussion

It was evident from presentations made to the Committee that much work on the space radiation problem has been completed, is under way, or is planned. At the same time, more information is urgently required in a number of areas. The character of the space radiation environment in regions of interest to the Air Force must be more completely determined. The effects of the radiation environment on a wide variety of materials and devices must be better understood and technology must be developed to enable the design and construction of equipment having required useful life in the space radiation environment. Steps should be taken to insure that needed information either is available or will be forthcoming from presently-planned experiments to enable sound engineering design of critical components and subassemblies for authorized and anticipated USAF space systems.

It is particularly important for the Air Force to coordinate its space radiation program with NASA to avoid needless duplication and gaps and to insure effective mutual assistance. Steps should be taken to provide adequate support (including separate launch and satellite vehicles, if necessary) for those space measurement programs which the Air Force clearly should undertake.

As stated in the USAF Space Program document*, "It is the Air Force objective to develop military capabilities applicable in space which (1) strengthen the general defense posture of the United States, and (2) protect the specific interests of the nation in the space region."

2.1 USAF Requirements

The USAF interest in space at this time is limited mainly to the region bounded by the so-called "synchronous" orbit. Operational systems to meet some requirements, such as communications, will extend out to synchronous orbit distances. However, most foreseeable Air Force systems will operate in the near-earth environment. On the other hand, NASA programs, by and large, are concerned with deeper space. This fundamental difference provides a useful basis for distinguishing between technical approaches and programs appropriate for the Air Force and for NASA.

Judgments regarding USAF needs for space radiation information must, at this time, be based upon assumed future operational requirements as well as upon the relatively few presently authorized space programs.

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*USAF Space Program S-3575, Nov. 62. (SECRET - Special Access)

Excluding manned space vehicles, the Air Force has actual or potential needs for spacecraft useful in the fields of reconnaissance, communications, early warning, navigation, and meteorology. Depending upon mission assignment, such craft may operate in regions characterized by high radiation intensities or in space relatively free of radiation effects. Since vehicle structural members and payload components exhibit varying degrees of degradation in intense radiation environments, a reasonably detailed knowledge of radiation flux levels and their variations in space and time appear essential for adequate specification of mission profiles and payload configuration.

An early effort should be made to examine presently authorized or proposed USAF satellites to assess their vulnerability to heavy radiation doses caused by natural or artificial radiation - including dosages which might be created by distant enemy low-yield nuclear explosions.

A further examination should be made of the design criteria which have been established for space vehicles in the initial planning stages (e.g., low altitude random communications satellites) to determine the extent to which presently available radiation environmental data have been used in the design of the system. If important information is missing, either on the space radiation environment or on radiation damage to components, to what extent can the lack be compensated by inexpensive overdesign?

It is apparent that much data already have been acquired to guide initial definition of the space radiation environment. However, continuing collection and evaluation of such information is required to enable formulation of models adequate to describe the fundamental physical processes involved in radiation trapping, distribution, and dumping. Equally important is the establishment of procedures for reducing experimental data to forms suitable for engineering applications.

Evidence already at hand indicates that artificially created radiation belts may exceed in intensity the natural belts by several orders of magnitude. Therefore, it appears highly desirable to undertake further studies directed toward improved understanding of trapping phenomena, belt enhancement, sweeping techniques, and related phenomena which may limit the space radiation environment which this nation or a potential enemy could create.

The apparently short lifetime of particles in the L-band from approximately 2 to 2.2 could be of practical importance, for example in the choice of altitudes for satellites which must survive a long time. Experiments should be undertaken soon to determine the reasons for this anomaly. Single measurements of air density at appropriate altitudes would be valuable.

A distinct possibility exists of inflicting damaging radiation dosages on unfriendly satellites with low yield nuclear explosions which occur at great distances from the target. Politically, such an attack might prove more feasible than a direct attack involving physical destruction. The Air Force should point out to those concerned with a nuclear test ban that the information needed to use nuclear explosions in this way cannot be obtained without further atmosphere tests.

In spite of the great vulnerability of conventional photographic material to radiation, both natural and man-made, it is necessary to depend upon photographic recording for important parts of the present Air Force space effort. Although ordinary photographic film has been adequate for present missions because of the choice of orbits which happen to coincide with a low intensity of natural radiation, it is unreasonable to expect this fortunate coincidence in future missions. Moreover even low-yield nuclear bursts would destroy photographic material at long ranges unless very heavy shielding were provided.

This situation has been recognized and projects are under way to develop less vulnerable recording media which might replace conventional photography. However, to our knowledge, nothing has yet been found which combines the high resolving power with high sensitivity to light of the silver halide emulsion, although some valuable recording media have been developed for special purposes.

It is recommended that greatly increased support be given to research on and development of new photo sensitive materials, or photosensitive systems, which might replace conventional photographic film, yet be relatively immune to high energy radiations.

From the ad hoc Committee's review of Air Force sponsored work on space radiation problems, several points seemed to stand out:

(1) It is widely recognized that too little is known quantitatively about characteristics of the radiation and its effect upon materials and components.

(2) Too many of the research efforts are fragmented and better oriented for purposes of science rather than for engineering of systems to meet operational requirements. There is need for better coordination and integration of programs being pursued by different USAF agencies - for example, AFSSD and AFCRL.

(3) The Air Force should recognize the need for more research on the space radiation environment to help avoid premature commitments to systems which may be doomed to failure because they have not been adequately engineered to survive in the space environment.

(4) There is undesirable fragmention of work on radiation damage and shielding, and

(5) The Air Force should undertake more centralized planning for space radiation studies and should take steps to insure continuing close communication and cooperation, at the working level, in each technical area, among its own research groups and with corresponding groups in NASA so that important and costly space measurements will be conducted efficiently.

2.2 Space Environment Monitoring

It appears that space radiation does not present design problems for many engineering materials unless they undergo sustained exposure for several years. However, for some materials such as those used in solar cells, conventional photographic recording systems, infrared sensors, and transistors, space radiation will be a very serious problem even with short exposures. Proper determination of requirements for component design and shielding is therefore of paramount importance.

In order to evaluate fully the problems encountered with space radiation, more information is urgently needed in the following areas:

(1) The character of the space radiation must be more completely specified.

(2) The interaction of these radiations with matter must be more fully understood.

(3) The effects of these radiations on specific materials and devices must be determined in detail.

(4) Technology must be developed to meet requirements for space radiation shielding.

Under the first area listed above, it should be emphasized that we must obtain considerably more detailed data about space radiation. Collection of these data will require many well instrumented, reliable space probes and may necessitate new measurement techniques. Both the energy spectra and time dependence of various forms of radiation must be measured carefully. Better understanding is required of time variations in the Van Allen belts and of the effects of solar-flare eruptions.

Under the second and third areas listed, there is need for more theoretical and experimental work on the interaction of high-energy protons with materials - particularly those used in semiconductor devices.

The fourth category, shielding, is probably one of the major problem areas, especially for manned space flight. However, requirements for effective shielding of electronic instruments may be eased substantially through development of microminiaturization techniques and self-compensating circuit designs.

More specifically, geophysical information needed to meet USAF requirements for space operations includes the following:

(1) More information on energetic particle radiation

over the polar regions and a better understanding of its relationship to ionospheric and auroral phenomena. This information is pertinent to the planning and design of equipment for a variety of USAF operations, including communications over the polar caps.

(2) Continuous observation and increased understanding of solar phenomena. Ultimately we need improved capability to predict at least a probability level of encountering energetic protons from the sun capable of producing damaging levels of radiation to USAF space missions. In this connection it is noted that the next interval of maximum solar activity (1968-70) probably will coincide with a time of rapidly increasing USAF space vehicle testing. Design and planning should take this solar activity into account.

(3) More quantitative information about and especially continual monitoring of geomagnetically trapped radiation. This type of radiation, which in the future may well include artificially injected as well as natural particles, is the most probable source of damage to USAF space vehicles, aside from the direct line-of-sight effects of nuclear explosions. It is, therefore, important that continual measurements be

made in support of space missions which must operate in or through the trapped radiation belts, both to establish a basis for prediction of natural variations in energy, intensity, and mirroring heights, and also to provide rapid knowledge about any artificially induced perturbations and the probable location and nature of the source. Such measurements also would be useful in gauging the effects of any experiments which might be undertaken relating to the feasibility of large scale "sweeping out" of trapped radiation.

The ad hoc Committee's review of planned USAF and NASA programs for space radiation measurements did not reveal any major gaps, except in the area of continual monitoring of geomagnetically trapped particles, where we believe there is need for simple, reliable, long-life satellites designed specifically for this purpose, together with suitable means for collecting, analyzing, and disseminating the results. The monitoring system, including the satellite, should be designed for highly-reliable, effective, and economical operation with reasonable accuracy and data density. Provision should be made for rapid replacement of monitoring satellites in the event of failure.

It is not our intention to prescribe either the exact type of instruments or the specific orbits for such satellites. These factors should be determined in orderly fashion following satisfactory completion of preliminary experiments now under way or authorized. However, attention is directed to the potential desirability of a near equatorial orbit, with instrumentation capable of measuring intensities and energy spectra along the magnetic field and normal to it. With proper selection of apogee and perigee such a satellite could sample the entire magnetosphere twice during each orbital period with a minimum requirement for data storage and/or read out capability.

The present practice of attempting to obtain space radiation data by pickaback experiments on satellites having other prime missions is judged to be wholly unsatisfactory. The proposed NASA orbiting observatories have objectives in deeper space than the region of primary USAF interest and are more complex, expensive, and as an inevitable result, less reliable. Wholly adequate monitoring of near space for USAF purposes could be accomplished with relatively simple vehicles which are within the current state of art. Conservative designs would assure a useful life of several years and the cost of obtaining continuing operational data would not be excessive.

The Air Force should now program funds and boosters in anticipation of such an operational requirement, recognizing that detailed characteristics of the payloads can be adequately specified only after completion of experiments now planned.

Particular attention should be given the problem of fully determining data on background radiation, solar radiation, and atmospheric density and composition at low altitudes, e.g., 100-500 nm.

Members of the research community engaged in planning or undertaking space measurements appear to be moderately well coordinated for the purposes of science. However, there appears to be an undesirable tendency to allow those who are qualified to undertake measurements to do so - without regard to the essential needs of USAF to obtain data essential for authorized or probable future space missions. At the same time, it must be recognized that the present state of knowledge of the space radiation environment is meagre. Collection of space radiation data should continue as a suitably oriented R & D program until essential and practicable USAF space mission objectives have been established. There now appears to be insufficient recognition of the fact that too little is known of the space environment to enable responsible development of military systems.

2.3 USAF/NASA Cooperation

The presentations to the ad hoc Committee, and information from other sources, indicate that effective collaboration is taking place between various scientists working on one or another aspect of the space radiation measurement program of USAF, NASA, and industry (Bell Telephone Laboratories, in particular). However, it is not clear that there is adequate central planning, either within USAF (as between AFSSD and AFCRL) or between USAF and NASA.

There appears to be a clear need for effective coordinated planning in this area on a national basis to insure fulfillment of future needs of both USAF and NASA for knowledge of space radiation environmental factors required for adequate protection and survival of both men and instruments in space. Notwithstanding formal agreements on basic policy which may have been reached between USAF and NASA, plans should be established for orderly detailed coordination of space radiation environment data collection programs and for sharing of results. In particular, USAF should plan to undertake independent space radiation measurements which are essential to their needs and which may not be completed adequately and in timely fashion under NASA programs. Close and effective collaboration is desirable, particularly in planning programs for continuing monitoring of the space radiation environment to insure that total national needs will be met as expeditiously and economically as possible.

2.4 Data Assimilation and Dissemination

Aside from the gratification of natural scientific curiosity, the prime purpose of USAF space radiation measurement programs should be to gain information which will be useful in the design and structuring of systems and components for essential space missions. Unless the information acquired from existing or projected USAF and NASA radiation measurement programs is reduced to forms intelligible to engineering personnel, much of the value of the exploratory scientific programs will be lost.

The Air Force should encourage and support one (or more) competent research groups to collate, interpret, and evaluate the results of all space radiation and materials effects programs - and to reduce these results to forms useful in designing and operating military space systems. It is most important that each such interpretative research group be physically and organizationally associated with one of the experimental data-collection research groups to insure maximum feed-back of information and ideas.

Knowledge of space radiation, like many other bodies of knowledge, suffers from the lack of an efficient system of assimilation and dissemination of information. A recent panel of PSAC has studied this typical problem and made a set of recommendations.*

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*"Science, Government, and Information - The Responsibilities of the Technical Community and the Government in the Transfer of Information," A Report of the President's Science Advisory Committee - January 10, 1963

The basic principle is the establishment of a "Data Center." Ideally the primary investigators themselves should present their findings in acceptable form. This could be insisted upon by clauses in contracts, but realistically this rarely works. Some organization must be given the assignment of assimilating and disseminating the gathered information.

This task has two aspects, the imaginative collection of data and documents, and their evaluation. In a field which can be reasonably well defined such as Space Radiation, these functions can be accomplished in several ways, a choice of which depends on the character of the effort and agencies currently involved. In this case it is recommended that the two basic functions be executed by two groups.

The identification and collection of pertinent information is not an impossible job at the present time, as it is in many other cases, and can be done, and indeed is done, within present USAF and NASA programs. The first suggestion is then that these two agencies continue, and expand the effort at Battelle Memorial Institute to provide the basic data base for this part of the space program. The present effort at Battelle is restricted to the effects of radiation on materials, especially from a structural point of view. This work is very satisfactory, and there seems to be no reason for change. A similar compilation of literature on the space environment is an additional requirement. The work at Battelle could be expanded to include this additional area or a new entity could be established in an appropriate environment, such as NBS or UCAR at Boulder, Colorado, where this kind of study already exists; AFCRL or NASA in Massachusetts; or near the Goddard Space Center. The advantages of these centers is that research is in progress which could profit by the proximity of the data center. (There is a proposal from the National Academy of Sciences which covers this requirement in considerable detail*.

Basic files, catalogs and abstracts should be established. Bibliographies and abstracts should be disseminated promptly, and without excessive editorial comment, to all agencies and contractors concerned. The JPL abstracts on space problems should be incorporated in this effort. There are grave dangers, however, in letting the undertaking rest at a bibliographical level.

The nature of a new field such as Space Radiation, especially in the early phases, is that the data and information is incomplete and heterogeneous and hard to assimilate into a coherent picture. It is therefore desirable to execute the second phase of digestion of available information. This takes time and thought of experts and experimentalists in the field, and should not encumber the basic collection and dissemination function.

*A proposal for a consolidated upper atmosphere and space data center was made by the Geophysics Research Board of the National Academy of Sciences. The GRB Panel on International Exchange of Geophysical Data, March 1962.

It would appear useful for special temporary study groups to be established periodically for the purpose of publishing coherent accounts (tentative perhaps) of the situation as interpreted by the data in hand. In this particular field the presentation can best be done by a kind of handbook, each section of which would be the result of a short term (e.g.,one-month) study effort.

Such groups should be comprised of:

(1) experts having first-hand knowledge of the data and the collection of data,

(2) professorial types in the general area, e.g., astronomers,

(3) professors, in the sense of expositors.

The handbook would have tutorial or survey articles of an encyclopedic nature. These should include descriptions or models of our current picture of space problems. Essential data should be presented in a consolidated and coordinated form. Methods of data reduction and use should follow. The handbook should be oriented towards supplying information for engineering design purposes. Space weather predictions will be of secondary importance for some years. Interpretation of data for intelligence would be a by-product and not expressed explicitly.

Typical sections of the handbook might be:

I. Astronomy (bearing specifically on Space Radiation)

The earth, its magnetic field

motion in the solar system

exposure to the sun's field

Aurora

Zodiacal light

Gegenshein

Maps

Other astronomical observations of pertinence

II. Description of particles and radiation in space.

Solar flares

Cosmic radiation

III. Effect of radiation on structural materials.

IV. Effect of radiation on circuit elements.

V. Shielding parameters and techniques

VI. Effects of radiation on system design

Space navigation

Satellite orientation

VII. Methods of calculating dosage for various orbits.

VIII. Computer programs

IX. Telemeter Data Processing methods.

Besides the production of a handbook, the study groups would be able to address themselves simultaneously to another task. It should become quite apparent that there are many lacunae in the data. The study groups should be established to make strong recommendations to SAB or directly to the Air Staff that certain types of data be collected. It is anticipated that, in its present state of freedom, investigations of space radiation will tend to make the easy measurements, and the most intriguing ones. It will, in the long run, be equally important to make a great many systematic but unglamorous measurements. In this connection, attention must be directed by the study groups, to the possibilities of ground based measurements of the radiation in space, even though these may not be as exciting as data collection from satellites.

3.0 Conclusions and Recommendations

(1) Much work on the space radiation environment is under way or is planned. However, too little is known for responsible development of military space systems.

(2) The research character of space radiation environment and shielding problems should be more fully recognized. There is need for improved coordination, direction, and support of the numerous space environmental research programs and materials effects programs to insure early attainment of engineering data essential for the design, construction and survival of required USAF space vehicles.

(3) The Air Force should take steps to improve the coordination of their in-house efforts in these areas, particularly among ASD, SSD and AFCRL.

(4) It is particularly important for USAF to coordinate their space radiation measurement programs with NASA to avoid needless duplication and gaps. Arrangements should be established to insure improved coordination at both policy/planning and working levels.

(5) The Air Force should plan adequate support (including separate boosters if required) for those space radiation environment measurements peculiar to their requirements and not expected to result in timely fashion from NASA programs. The present USAF practice of attempting to obtain space radiation data by pickaback experiments on satellites carrying other prime payloads is judged to be unsatisfactory. For many measurements, separate vehicles are indicated.

(6) The Air Force should undertake a critical review of presently authorized or planned space systems to determine the sufficiency of design criteria which have been, or can be, used to insure reliable operation with desired life expectancy in the space radiation environment.

(7) USAF, in collaboration with NASA, should evaluate the need for a future space radiation environment monitoring service. The Air Force should identify and prepare to support adequately all space monitoring functions peculiar to USAF needs and not planned by NASA.

(8) It is recommended that increased support be given to research on new photosensitive materials and systems which might replace conventional photographic film and be relatively immune to high energy space radiations.

(9) The Air Force should emphasize to authorities concerned with nuclear test bans that without further atmospheric testing it will be impossible to determine the vulnerability of satellites to heavy radiation dosages which may be inflicted by low-yield nuclear explosions at great distances.

(10) The Air Force should establish one or more centers for the collection, assimilation, and dissemination of space radiation and materials effects data along the lines discussed in sec. 2.4 above. It is particularly important for available data to be reviewed periodically by qualified groups and reduced to handbook form for use by space vehicle designers.

Appendix I

MISSION OF THE AD HOC COMMITTEE ON SPACE RADIATION EFFECTS

The committee proposes to review the effects of natural and artificial particle and electromagnetic radiation, particularly trapped and solar radiation, on the materials, electronic and optical components, and the performance of space vehicle systems. Propagation effects will be considered.

The review will not cover biomedical effects or nuclear blast effects. The radiation effects of nuclear power and propulsion systems will not be covered initially, but may be included later.

The review will emphasize present state of knowledge in the following areas:

(1) Space radiation environment and need for additional data.

(2) Effects on materials, components and system performance.

(3) Design criteria for protection from the space radiation environment.

13 December 1962